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(54) **A beta titanium alloy**

Legierung auf Titan-Basis mit Beta-Stuktur

Un alliage de titane de phase beta

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[0022] A gas turbine engine compressor blade 10, as shown in figure 1, comprises an aerofoil 12, a platform 14 and a root 16. The compressor blade 10 comprises a beta titanium alloy, preferably a burn resistant beta titanium alloy, according to the present invention. The beta titanium alloy compressor blade may be forged, or cast, or produced by other thermomechanical processes.

[0023] A gas turbine engine compressor blade 20, as shown in figure 2, comprises an aerofoil 22, a platform 24 and a root 26. The compressor blade 10 also comprises a tip portion 28 on the extremity of the aerofoil 22 remote from the platform 24 and root 26. The tip portion 28 comprises a beta titanium alloy, preferably a burn resistant titanium alloy according to the present invention. The tip portion 28 may comprise weld filler deposited onto the aerofoil 22 by using the burn resistant beta titanium alloy as the weld filler during welding, e.g. tungsten inert gas (TIG) welding. The weld filler subsequently being machined to size and shape. Alternatively the tip portion 28 may comprise a block of the burn resistant beta titanium alloy which is welded onto the aerofoil, e.g. tungsten inert gas (TIG) welding, laser welding, electron beam welding etc. The block subsequently being machined to size and shape.

[0024] The burn resistant titanium alloy according to the present invention comprises 20 to 30wt% vanadium, 13 to 17w% chromium, 1.0 to 3.0wt% aluminium, 0.1 to 0.4wt% carbon, up to 0.2wt% oxygen and the balance titanium plus incidental impurities. Preferably the beta titanium alloy comprises 23-27wt% vanadium, 13-17wt% chromium, 1-3wt% aluminium, up to 0.15wt% oxygen, 0.1 to 0.3wt% carbon and the balance titanium plus incidental impurities. Preferably the beta titanium alloy comprises 25wt% vanadium, 15wt% chromium, 2wt% aluminium, up to 0.15wt% oxygen, 0.1 to 0.3wt% carbon and the balance titanium plus incidental impurities.

[0025] The burn resistant beta titanium alloy in particular has a favourable combination of carbon and oxygen which enhances the ductility of the burn resistant titanium alloy. It has been found that there is a synergy between the oxygen and carbon levels. In particular it has been found that the carbon reacts with the titanium to form titanium carbide (Ti_2C) precipitates which refine the grain size of the beta titanium alloy matrix.

[0026] Furthermore the titanium carbide (Ti_2C) precipitates have an affinity for the oxygen and the oxygen becomes attached to the titanium carbide (Ti_2C) precipitates and thus the oxygen is removed from the beta titanium alloy matrix. The presence of oxygen in the beta titanium alloy matrix has the effect of promoting the precipitation of alpha titanium in the beta titanium alloy matrix. The presence of alpha titanium in the beta titanium alloy reduces the ductility of the beta titanium alloy. Thus because the titanium carbide precipitates remove oxygen from the beta titanium alloy matrix there is less oxygen available to promote the precipitation of the alpha titanium, and thus the precipitation of alpha titanium in the beta titanium alloy matrix is reduced. Therefore this increases the ductility of the beta titanium alloy. It is to be noted that the carbon does not remove all the oxygen from the beta titanium alloy matrix.

[0027] It has been found that titanium carbide (Ti_2C) precipitates are formed when more than 0.1wt% carbon is present in the beta titanium alloys mentioned above. These titanium carbide precipitates getter the oxygen and refine the grains. The carbon addition improves the stability of the beta titanium alloys.

[0028] The increase in the ductility of the beta titanium alloy provided by the synergy between the oxygen and the carbon enables aluminium to be added to the beta titanium alloy, and this enables the use of cheaper master alloys, e.g. vanadium aluminium master alloys.

EXAMPLES

[0029] Alloys with the composition listed in table 1 were produced using a plasma melter from mixtures of master alloys and elemental raw materials. Either titanium sponge with 0.04wt% oxygen or titanium granules with 0.086wt% oxygen were used according to the desired oxygen levels. The base level of carbon with no deliberate addition of carbon is 0.02wt% carbon which was brought in by impurities in the raw materials.

TABLE 1

(Composition in weight%)						
Alloy	Elements					
Code	Ti	V	Cr	Al	C	O
A8	Balance	25	15	2	0.02	0.065
A14	Balance	25	15	2	0.02	0.095
A12	Balance	25	15	2	0.02	0.135
A17	Balance	25	15	2	0.10	0.115
A18	Balance	25	15	2	0.20	0.110
A11	Balance	25	15	2	0.30	0.095
A13	Balance	25	15	2	0.09	0.165

TABLE 1 (continued)

(Composition in weight%)						
Alloy	Elements					
Code	Ti	V	Cr	Al	C	O
A19	Balance	25	15	2	0.21	0.15
A20	Balance	25	15	2	0.31	0.15

[0030] The alloy samples were all forged at 1050°C to produce pancakes about 16mm thick. The samples were then heat treated at 850°C for 2 hours air cooled, or heat treated at 1050°C for 0.5 hours air cooled followed by ageing at 700°C for 4 hours air cooled or heat treated at 1050°C for 0.5 hours air cooled then followed by ageing at 700°C for 4 hours air cooled and then followed by heat treatment at 550°C for 500 hours air cooled.

[0031] The alloy samples were cut, polished and etched for conventional optical microscopy and scanning electron microscopy. Additionally X-ray diffraction, EDX and transmission electron microscopy were performed on the alloy samples. All the alloy samples were tested in tension at room temperature, and the results are listed in table 2 and illustrated graphically in figure 3.

Condition 1:- 850°C/2 hours air cooled.
Condition 2:- 1050°C/0.5 hours air cooled and 700°C/4 hours air cooled.
Condition 3:- 1050°C/0.5 hours air cooled and 700°C/4 hours air cooled and 550°C/500 hours air cooled.

[0032] The carbon in alloys A8, A14 and A12 are impurities in the alloy rather than deliberate addition of carbon.

TABLE 2

(Tensile Properties)				
Alloy Code	Heat Treat Conditions	0.2% Proof Stress (MPa)	Ultimate Tensile Strength (MPa)	Elongation (%)
A8	1	828	858	21.0
A14	1	805	842	1.5
	2	892	892	1.4
	3	953	955	0.6
A12	1	835	853	0.5
	2		902	0.1
	3	949	949	0.3
A17	1	916	921	24.0
	2	878	891	16.4
	3	887	896	4.9
A18	1	899	939	20.3
	2	894	923	15.0
	3	849	891	11.8
A11	1	867	905	16.6
	2	866	882	14.0
	3	849	891	4.6
A13	1		891	0
	2	938	944	0.5
A19	1	900	914	8.4
	2	882	903	8.7
	3	890	911	9.9
A20	1	935	964	10.9
	2	903	915	1.0
	3	885	927	10.5

[0033] It is clear from table 2, and figure 3, that when there is no deliberate carbon addition the trend is for the elongation, the ductility, to decrease with increasing oxygen levels. It is also clear that when carbon is added the elongation, ductility, is improved. It is seen that there is a significant increase in ductility by adding over 0.1wt% carbon to beta titanium alloys with 0.095 to 0.115wt% oxygen, see alloys A14, A17, A18 and A11. The improvement in ductility for alloys with 0.15 to 0.165wt% oxygen and over 0.2wt% carbon is also significant for most of the heat treatments. It is seen that the ductility of the beta titanium alloys without carbon addition deteriorates after heat treatment condition 3. This is due to precipitation of alpha titanium in the beta titanium alloy matrix. The ductility of the beta titanium alloys with carbon addition also deteriorates after heat treatment. However, some ductility is retained. Also the ductility of alloys A19 and A20 with high carbon and high oxygen levels have greater ductility than alloy A17 with lower carbon and oxygen levels after heat treatment condition 3.

[0034] Examination showed that the alloy samples without carbon failed by cleavage fracture, whereas alloy samples with carbon failed by a ductile, or by a mixture of ductile/brittle, manner.

[0035] The addition of carbon overcomes the detrimental effects that oxygen and alpha titanium have on the room temperature ductility of the beta titanium alloy and the metallurgical stability of the beta titanium alloy after high temperature exposure.

[0036] The titanium carbide precipitates formed are stable to heat treatment and these titanium carbide precipitates refine the as forged and heat treated microstructure and as cast microstructure. The refined microstructure may deform more uniformly and may have an effect on the ductility of the beta titanium alloy. The titanium carbide precipitates getter oxygen, increase the ductility of the beta titanium alloy matrix and suppress the formation of the alpha titanium in the beta titanium alloy matrix. The refined beta titanium alloy matrix has smaller grains and thus there are more grain boundaries. The amounts of alpha titanium precipitation present on each grain boundary is less and this further increases ductility by reducing embrittlement due to alpha titanium. The carbon level must not be too high in the beta titanium alloys, since the precipitation of too much titanium carbide is detrimental to ductility.

[0037] It is well known in the art that the addition of carbon to beta titanium alloys produces titanium carbides. It is also well known that beta titanium alloys become brittle due to titanium carbide precipitation. Thus this improvement in ductility of the beta titanium alloy due to the higher than normal addition of carbon in the presence of the oxygen is completely unexpected.

[0038] Although the invention has been described with reference to a narrow range of beta titanium alloys it is believed that it is applicable to all beta titanium alloys with more than 10wt% of one or more beta stabilising elements and oxygen present, which decreases the ductility of the beta titanium alloy by stabilising alpha titanium, or alpha 2 titanium, in the beta titanium alloy matrix. The beta stabilising element may be one or more of the elements vanadium, molybdenum, tantalum, niobium, chromium, tungsten, manganese, copper, nickel and iron.

[0039] The advantages provided by the present invention are an increase in the ductility of the beta titanium alloy provided by the synergy between the oxygen and the carbon. This enables aluminium to be added to the beta titanium alloy; and this enables the use of cheaper master alloys, e.g. vanadium aluminium master alloys. There may also be an improvement in the processing temperature range.

[0040] The prior art mentioned above does not disclose, or suggest, that there is a synergy between carbon and oxygen in beta titanium alloys which increases the ductility of the beta titanium alloy.

[0041] Although the Invention has been described with reference to the use as compressor blades and compressor vanes, it may also be used to make compressor casings and other suitable components for gas turbine engines or other engines and for other applications.

Claims

1. A beta titanium alloy comprising at least 10wt% of one or more beta stabilising elements, the beta stabilising element is selected from the group comprising vanadium, molybdenum, tantalum, niobium, chromium, tungsten, manganese, copper, nickel and iron, 1.0 to 3.0 wt% aluminium, 0.1 to 0.4wt% carbon up to 0.2wt% oxygen and the balance titanium and incidental impurities, wherein the carbon is present in the form of titanium carbide precipitates distributed throughout the beta titanium alloy matrix, the titanium carbide precipitates consisting of Ti_2C titanium carbide precipitates, the titanium carbide precipitates refine the grain size of the beta titanium alloy matrix and remove oxygen from the beta titanium alloy matrix to reduce precipitation of alpha titanium in the beta titanium alloy matrix to increase the ductility of the beta titanium alloy.

2. A beta titanium alloy as claimed in claim 1 wherein the beta titanium alloy comprises 20 to 30wt% vanadium, 13 to 17wt% chromium, 1.0 to 3.0wt% aluminium, 0.1 to 0.4wt% carbon, up to 0.2wt% oxygen and the balance titanium plus incidental impurities

3. A beta titanium alloy as claimed in claim 1 or claim 2 wherein the beta titanium alloy comprises 1.5 to 2.5wt% aluminium.

4. A beta titanium alloy as claimed in claim 1, claim 2 or claim 3 wherein the beta titanium alloy comprises 0.15 to 0.3wt% carbon.

5. A beta titanium alloy as claimed in any of claims 1 to 4 wherein the beta titanium alloy comprises less than 0.15wt% oxygen.

6. A beta titanium alloy as claimed in any of claims 1 to 5 wherein the beta titanium alloy comprises 23-27wt% vanadium, 13-17wt% chromium, 1-3wt% aluminium, up to 0.15wt% oxygen, 0.1 to 0.3wt% carbon and the balance titanium plus incidental impurities.

7. A beta titanium alloy as claimed in claim 6 wherein the beta titanium alloy comprises 25wt% vanadium, 15wt% chromium, 2wt% aluminium, up to 0.15wt% oxygen, 0.1 to 0.3wt% carbon and the balance titanium plus incidental impurities.

8. An article (10)comprising a beta titanium alloy as claimed in any of claim 1 to 7.

9. An article (10) as claimed in claim 8 wherein the article (10) comprises a component for a gas turbine engine.

10. An article as claimed in claim 9 wherein the component (10) comprises a compressor blade or a compressor vane.

11. An article as claimed in claim 9 wherein the component (28) comprises a tip portion for a compressor blade (20).

Patentansprüche

1. Titan-Legierung mit Beta-Struktur mit wenigstens 10 Gew. % eines oder mehrerer Beta-Stabilisierungselemente, wobei das Beta-Stabilisierungselement aus der Gruppe ausgewählt ist, die folgende Elemente aufweist: Vanadium, Molybden, Tantal, Niob, Chrom, Wolfram, Mangan, Kupfer, Nickel und Eisen und die Titan-Legierung weiter 1,0 - 3,0 Gew. % Aluminium, 0,1 - 0,4 Gew. % Kohlenstoff und bis zu 0,2 Gew. % Sauerstoff und im übrigen Titan und zufällige Verunreinigungen enthält, wobei der Kohlenstoff in Form von Titan-Karbid-Ausscheidungen vorhanden ist, die über die Beta-Titan-Legierungsmatrix verteilt sind, und wobei die Titan-Karbid-Ausscheidungen aus Ti_2C-Titan-Karbid-Ausfällungen bestehen und die Titan-Karbid-Ausscheidungen die Korngröße der Beta-Titan-Legierungsmatrix verbessern und Sauerstoff aus der Titan-Legierungsmatrix entfernen, um die Ausscheidung von Alpha-Titan in der Beta-Titan-Legierungsmatrix zu reduzieren und um die Verformbarkeit der Beta-Titan-Legierung zu verbessern.

2. Titan-Legierung mit Beta-Struktur nach Anspruch 1, bei welcher die Beta-Titan-Legierung 20 - 30 Gew. % Vanadium, 13 - 17 Gew. % Chrom, 1,0 - 3,0 Gew. % Aluminium, 0,1 - 0,4 Gew. % Kohlenstoff und bis zu 0,2 Gew. % Sauerstoff und im übrigen Titan plus zufällige Verunreinigungen enthält.

3. Titan-Legierung mit Beta-Struktur nach den Ansprüchen 1 oder 2, bei welcher die Beta-Titan-Legierung 1,5 - 2,5 Gew. % Aluminium enthält.

4. Titan-Legierung mit Beta-Struktur nach Anspruch 1, 2 oder 3, bei welcher die Beta-Titan-Legierung 0,15 - 0,3 Gew. % Kohlenstoff enthält.

5. Titan-Legierung mit Beta-Struktur nach einem der Ansprüche 1 bis 4, bei welcher die Beta-Titan-Legierung weniger als 0,15 Gew. % Sauerstoff enthält.

6. Titan-Legierung mit Beta-Struktur nach einem der Ansprüche 1 bis 5, bei welcher die Beta-Titan-Legierung 23 - 27 Gew. % Vanadium, 13 - 17 Gew. % Chrom, 1 - 3 Gew. % Aluminium, bis zu 0,15 Gew. % Sauerstoff, 0,1 - 0,3 Gew.% Kohlenstoff und im übrigen Titan und zufällige Verunreinigungen enthält.

7. Titan-Legierung mit Beta-Struktur nach Anspruch 6, bei welcher die Beta-Titan-Legierung 25 Gew. % Vanadium, 15 Gew. % Chrom, 2 Gew. % Aluminium, bis zu 0,15 Gew. % Sauerstoff, 0,1 - 0,3 Gew. % Kohlenstoff und im

übrigen Titan plus zufällige Verunreinigungen enthält.

8. Gegenstand (10), bestehend aus einer Titan-Legierung mit Beta-Struktur nach einem der Ansprüche 1 bis 7.

9. Gegenstand (10) nach Anspruch 8, wobei der Gegenstand (10) ein Bauteil für ein Gasturbinentriebwerk ist.

10. Gegenstand nach Anspruch 9, wobei der Bauteil (10) eine Kompressor-Laufschaufel oder eine Kompressor-Leitschaufel ist.

11. Gegenstand nach Anspruch 9, bei welchem der Bauteil (28) ein Spitzenteil einer Kompressorschaufel (20) ist.

Revendications

1. Alliage de titane bêta comprenant au moins 10% en poids d'un ou plusieurs éléments stabilisants bêta, l'élément stabilisant bêta étant choisi à partir du groupe comprenant le vanadium, le molybdène, le tantale, le niobium, le chrome, le tungstène, le manganèse, le cuivre, le nickel et le fer, 1.0 à 3.0% en poids d'aluminium, 0.1 à 0.4% en poids de carbone, jusqu'à 0.2% en poids d'oxygène et le reste de titane et d'impuretés incidentes, dans lequel le carbone est présent sous la forme de précipités de carbure de titane distribués à travers toute la matrice d'alliage de titane bêta, les précipités de carbure de titane consistant en des précipités de carbure de titane Ti_2C, les précipités de carbure de titane affinant la grosseur du grain de la matrice d'alliage de titane bêta et retirant de l'oxygène à partir de la matrice d'alliage de titane bêta pour réduire la précipitation de titane alpha dans la matrice d'alliage de titane bêta pour augmenter la ductilité de l'alliage de titane bêta.

2. Alliage de titane bêta selon la revendication 1, dans lequel l'alliage de titane bêta comprend 20 à 30% en poids de vanadium, 13 à 17% en poids de chrome, 1.0 à 3.0% en poids d'aluminium, 0.1 à 0.4% en poids de carbone, jusqu'à 0.2% en poids d'oxygène et le reste de titane plus des impuretés incidentes.

3. Alliage de titane bêta selon la revendication 1 ou la revendication 2, dans lequel l'alliage de titane bêta contient 1.5 à 2.5% en poids d'aluminium.

4. Alliage de titane bêta selon la revendication 1, la revendication 2 ou la revendication 3, dans lequel l'alliage de titane bêta comprend 0.15 à 0.3% en poids de carbone.

5. Alliage de titane bêta selon l'une quelconque des revendications 1 à 4, dans lequel l'alliage de titane bêta comprend moins de 0.15% en poids d'oxygène.

6. Alliage de titane bêta selon l'une quelconque des revendications 1 à 5, dans lequel l'alliage de titane bêta comprend 23 à 27% en poids de vanadium, 13 à 17% en poids de chrome, 1 à 3% en poids d'aluminium, jusqu'à 0.15% en poids d'oxygène, 0.1 à 0.3% en poids de carbone et le reste de titane plus des impuretés incidentes.

7. Alliage de titane bêta selon la revendication 6, dans lequel l'alliage de titane bêta comprend 25% en poids de vanadium, 15% en poids de chrome, 2% en poids d'aluminium, jusqu'à 0.15% en poids d'oxygène, 0.1 à 0.3% en poids de carbone, et le reste de titane plus des impuretés incidentes.

8. Objet (10) comprenant un alliage de titane bêta selon l'une quelconque des revendications 1 à 7.

9. Objet (10) selon la revendication 8 dans lequel l'objet (10) comprend un composant pour un moteur à turbine à gaz.

10. Objet selon la revendications 9 dans lequel le composant (10) comprend une pale de compresseur ou une aube de compresseur.

11. Objet selon la revendication 9 dans lequel le composant (28) comprend une partie de bout pour une pale de compresseur (20).

Fig.1.

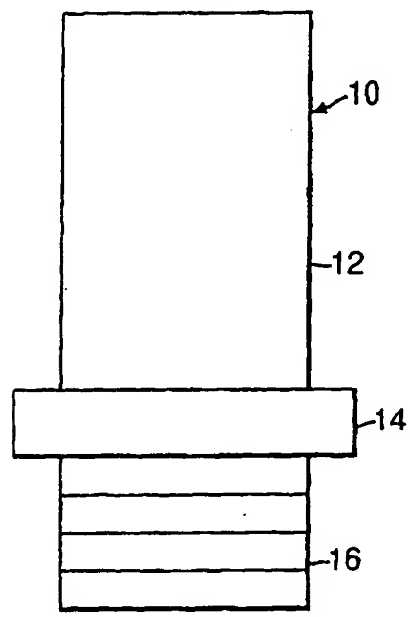


Fig.2.

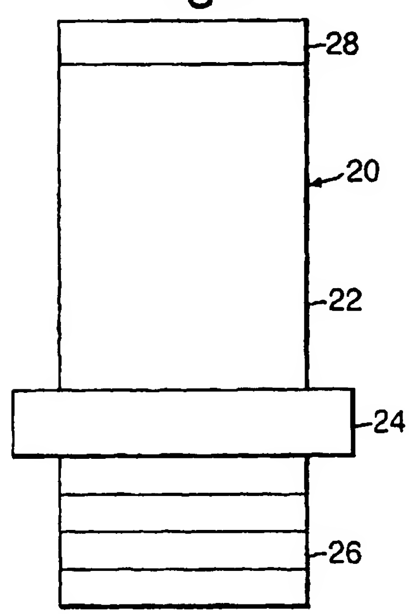
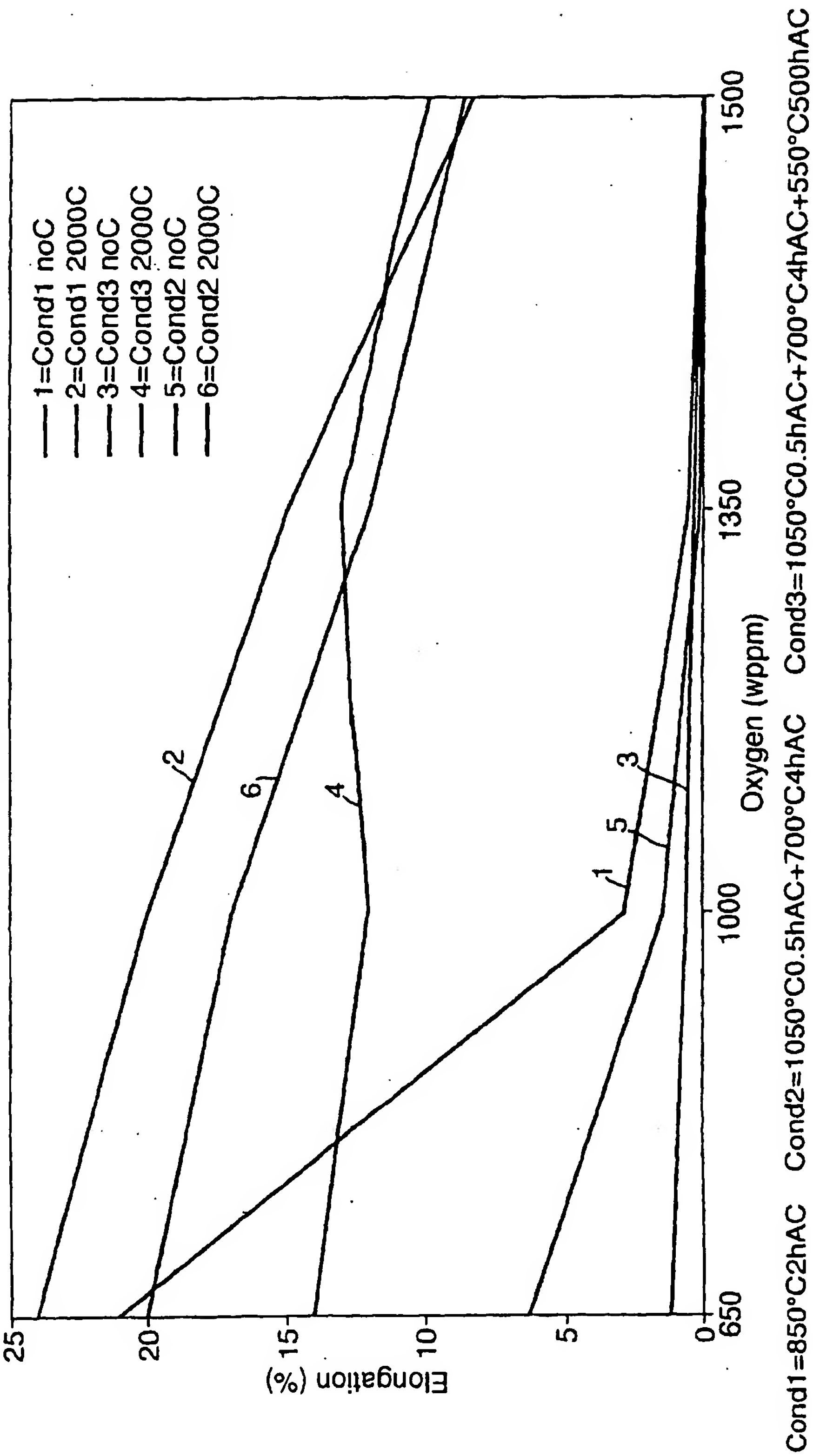


Fig.3.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2=Cond1 2000C
3=Cond3 noC
4=Cond3 2000C
5=Cond2 noC
6=Cond2 2000C
Elongation (%)
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5
10
15
20
25
650
1000
1350
1500
Oxygen (wppm)
1
2
3
4
5
6
Cond1=850°C2hAC Cond2=1050°C0.5hAC+700°C4hAC Cond3=1050°C0.5hAC+700°C4hAC+550°C500hAC